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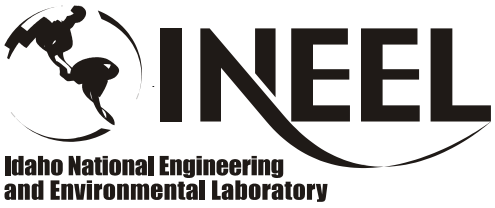

Advanced Technology Vehicle Testing

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41st Power Sources

ADVANCED TECHNOLOGY VEHICLE TESTING

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Abstract: The goal of the U.S. Department Energy's Advanced Vehicle Testing Activity (AVTA) is to increase the body of knowledge as well as the awareness and acceptance of electric drive and other advanced technology vehicles (ATV). The AVTA accomplishes this goal by testing ATVs on test tracks and dynamometers (Baseline Performance testing), as well as in real-world applications (Fleet and Accelerated Reliability testing, and public demonstrations). This enables the AVTA to provide Federal and private fleet managers, as well as other potential ATV users, with accurate and unbiased information on vehicle performance and infrastructure needs so they can make informed decisions about acquiring and operating ATVs. The ATVs currently in testing include vehicles that burn gaseous hydrogen (H2) fuel and hydrogen/CNG (H/CNG)-blended fuels in internal combustion engines (ICE), and hybrid electric (HEV), urban electric, and neighborhood electric vehicles. The AVTA is part of DOE's FreedomCAR and Vehicle Technologies Program

Keywords: hydrogen; H/CNG; electric vehicle; HEV; hybrid electric vehicle; NEV; vehicle testing.

Hydrogen Station and Hydrogen ICE Vehicle Testing

Arizona Public Service Alternative Fuel Pilot Plant: The AVTA teamed with Electric Transportation Applications (ETA) and Arizona Public Service (APS) to develop the APS Alternative Fuel Pilot Plant (Figure 1), which produces and compresses H2 on site. The H2 is produced through an electrolysis process that separates water into hydrogen and oxygen, by operating a PEM fuel cell in reverse. The Pilot Plant also compresses natural gas on site.

Figure 1. APS Alternative Fuel Pilot Plant and fueling pumps.

The hydrogen subsystem includes hydrogen output (99.9997% purity) at the fuel cell at 150 psi; the H2 is then dried and stored (9,000 scf) at low pressure (150 psi). The H2 is next compressed, filtered, and stored (17,000 scf) at 6,100 psi, where it is ready for use.[1]

The CNG subsystem compresses natural gas from street service via a boost compressor (60 psi) and a main compressor (5,000 psi). Using six storage tanks, the CNG is stored using a three-stage cascade pressure arrangement at 3,600, 4,500 and 5,000 psi.

The APS Alternative Fuel Pilot Plant includes fuel dispensers and credit card billing, and it is used to fuel vehicles that operate on 100% H2 and blends of 15 to 50% H/CNG at pressures up to 5,000 psi.

Hydrogen ICE Vehicle Testing: The H2 ICE test vehicles that use the H2 and HCNG fuel produced by the Pilot Plant include:

- 100% H2 Mercedes Benz van
- Ford F-150, operating on up to 30% H/CNG
- Ford F-150, operating on up to 50% H/CNG
- Dodge van operating on 15% H/CNG
- Eight APS meter reader vehicles (S-10 and Sierra pickups, and Blazers) operating on 15% H/CNG
- Ford F-150, operating on 100% H2, 5.6 liter 32 valve high-efficiency engine
- Ford F-150, operating on 100% H2, 5.4 liter 16 valve engine.

To date, the H2 ICE test vehicles have accumulated 250,000 test miles while being fueled with H2 and H/CNG.

Figure 2. Ford F-150 instrumented for acceleration testing.

The 30% blend H/CNG F-150 was performance (range, acceleration, fuel economy) tested on three fuels – 100% CNG, 15% H/CNG and 30% H/CNG (Table 1). Emissions testing was also conducted on the 30% H/CNG F-150 several times, using both the Inspection and Maintenance Driving Cycle (IM-240) and Federal Test Procedure 75 (FTP-75) test cycles. Carbon monoxide emissions from the 30% blend F-150 averaged 0.26 g/mi over the FTP-75 tests, under the California SULEV standard of 1 g/mi. Nitrogen oxide emissions averaged 0.078 g/mi, near the California ULEV standard of 0.07.

Table 1. 30% H/CNG F-150 performance testing results.[2]

Fuel	Acceleration to 60 mph (seconds)	Fuel (miles /gge)	Range (miles)
CNG	10.10	23.3	122
15% H/CNG	10.97	22.6	110
30% H/CNG	12.68	23.5	102

Hybrid Electric Vehicle TESTING

HEV Accelerated Reliability and Fleet Testing: The AVTA has four different models (Honda Civic, Honda Insight, model year 2002/2003 Toyota Prius, and model year 2004 Prius) of HEVs in fleet and accelerated reliability testing. In HEV accelerated reliability testing, each vehicle is operated until it achieves 160,000 miles unless the vehicle becomes inoperable due to an accident or maintenance/ repair limitations.

The 16 HEVs (Table 2) have accumulated over 850,000 test miles as of January 2004; the number of test vehicles per model, the miles driven per HEV model, and the average miles per gallon fuel economy are shown in the table. (The model year 2004 Toyota Prius, which is significantly different from the 2002 and 2003 model, is just entering testing, and testing results were not yet available). Fleet drivers are operating the HEVs in various routes throughout Arizona in the following fleets: Bank One, Red Cross, APS, and ETA.

On a monthly basis, the total average fuel economy for the four Honda Civic HEVs averaged between 34.5 and 42.1 miles per gallon (mpg); the six Honda Insight HEVs averaged between 41.6 and 53.8 mpg; and the six Toyota Prius HEVs averaged between 36.5 and 51.3 mpg. (Because the monthly mpg results for a single vehicle can be highly influenced if a fueling occurs right before or right after the end-of-month data collection cutoff, only the average results for all test vehicles are discussed).

Table 2. HEV test vehicle models, number of test units (No.#), average fuel economy (mpg), and Environmental Protection Agency (EPA) fuel economy.

HEV Model	No.	Miles (1/1/04)	MPG	EPA Estimate City/Highway[3]
Civic	4	236,000	38.2	47/48
Insight	6	292,000	45.8	57/56
Prius (02/03)	6	333,000	41.0	52/45

As seen in Table 2, the HEVs in Fleet testing are not exhibiting the same fuel economy as the EPA-reported fuel economies. When compared to the average EPA-reported fuel economy (city + highway / 2), the Civics and Insights in Fleet testing are both getting about 80% of the estimated EPA average, and the Prius HEVs are getting 85% of the estimated EPA average. This may be due to the nature of the applications the vehicles are used in. Generally, the fleet drivers are more concerned with accomplishing their tasks than maximizing fuel economy. However, given the number of test miles accumulated, the Fleet testing fuel economy results likely represent the fuel economies other fleets would encounter.

Examining the graphed monthly average fuel economy for each group of HEV models (Figure 3) suggests a correlation between lower fuel economy during summer time warm/hot weather months and higher fuel economy during winter time cool/cold weather months. This is evident for all three HEV models. Causes may include greater use of air conditioning in terms of time used, increased vehicle idling times in order to keep the air conditioning on, and the air conditioning turned to maximum levels. The likely cause is probably some combination of all three.

In addition to fuel use, other data being collected include standard maintenance and repair records, as well as any abnormalities unique to HEVs. The results will be reported for each vehicle and each group of the same vehicle models as the vehicles complete testing. The HEV components for all three models have performed well, though one model is having transmission problems at higher mileages, and steering subsystems are producing problems on another model.

Hybrid Electric Vehicle Baseline Performance Testing: The Baseline Performance HEV test parameters include acceleration, gradeability, handling, maximum speed, and braking, as well as two fuel economy tests. Both fuel economy tests are conducted identically (SAE J1634),[4] with the exception that one is conducted with the air conditioning off, the other with the air conditioning on maximum. To date, the Civic, Insight, and (2002/2003) Prius have all undergone Baseline Performance testing.

The drive cycle fuel economy testing results with the air conditioning off compared to the air-conditioning-on-maximum testing averaged a difference of 12.1 mpg higher for the three HEVs. The Insight had the highest delta, with 13.5 higher mpg with the air conditioning off than on maximum (Figure 4).

Compared to the EPA fuel economy results (Figure 4), only the drive cycle testing with the air conditioning off resulted in mpg values near the EPA results. The fuel economy as measured for each HEV model during the 850,000 miles of fleet and accelerated reliability testing (yellow bars) was between the dynamometer drive cycle test results for the air-conditioning-on-maximum tests (blue bars) and drive

cycle test results with the air conditioning off (red bars), which suggests that the two AVTA SAE J1634 tests are accurate measures of real-world fuel economy experienced during HEV fleet operations.

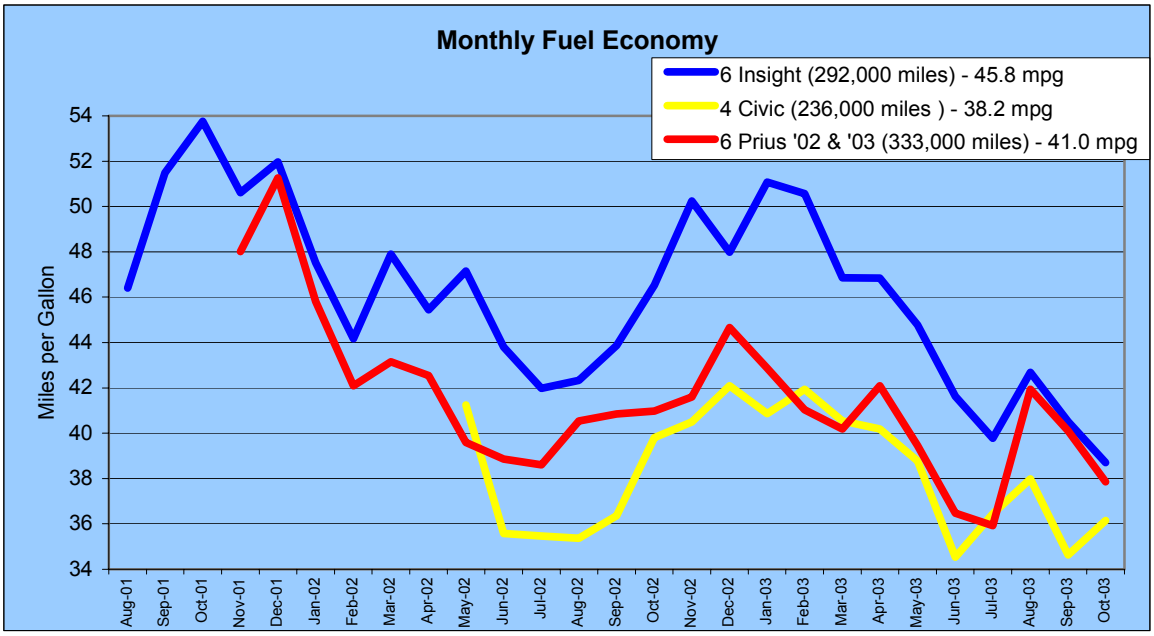

Figure 3. Cumulative and monthly average fuel economy (miles per gallon) values for six Honda Insight, four Honda Civic, and six Toyota Prius hybrid electric vehicles.

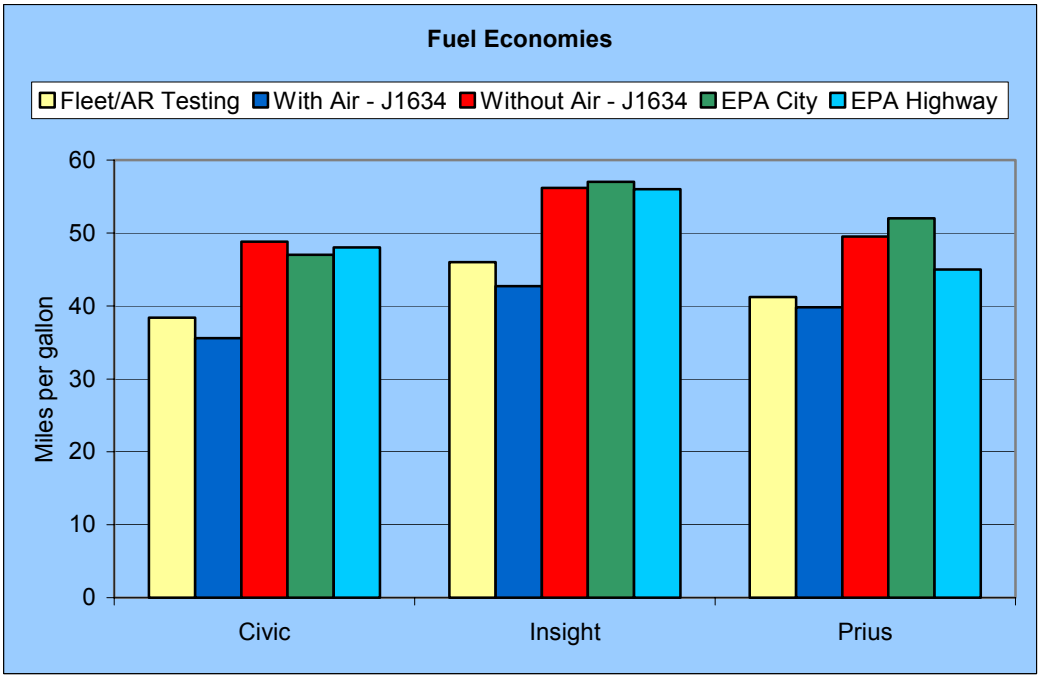

Figure 4. Honda Civic, Honda Insight, and Toyota Prius HEV fuel economy measurements, including SAE J1634 with air-conditioning-on-maximum (dark blue bar), fleet operations and accelerated reliability testing (yellow bar), SAE J1634 testing with air conditioning off (red bar) and EPA city (green bar) and highway (light blue/aqua bar) estimated fuel economies.

Neighborhood Electric Vehicles

Neighborhood electric vehicles (NEVs), which have top speeds of 20 to 25 miles per hour and are legal in about 45 states on roads generally up to 35 miles per hour, are increasingly being used in many applications, ranging from National Parks such as Yellowstone and Yosemite, to military reservations such as Luke Air Force Base (with over 400 NEVs), extensively in retirement and planned communities, and even in cold weather states such as Idaho. Given the relatively low manufacturing

infrastructure investment requirements, the barriers to entering the NEV manufacturer market have resulted in several new NEV products being announced, though never being manufactured in any number. In addition, NEV customers are often experiencing battery propulsion for the first time, and they may be unaware of such issues as battery watering needs for lead acid batteries, the tradeoffs between power and energy use, potential maintenance and life benefits of advanced battery chemistries, or charging methodologies and requirements (including fast charging). In order to educate potential NEV users, sustain the growth of a quality NEV market, and support wise financial investments by Federal and private fleets as well as the public, the AVTA initiated the Baseline Performance and Fleet testing NEVs.

NEV Baseline Performance Testing: The NEV baseline performance testing[5] parameters include acceleration, gradeability, handling, maximum speed, maximum range, braking, charger efficiency, charging time, and compliance with Federal Motor Vehicle Safety Standard No. 500.

The ten NEV models Baseline Performance tested had an overall average range of 37.8 miles per charge (Figure 5). Charging time for the two TH!NK *city* NEVs was 8.3 hours; for the four Global Electric Motors (GEM) NEVs it was 9.4 hours; and for the two ParCars it was 11.3 hours. These vehicles were all charged at Level I (115 to 120 VAC). The two Frazer-Nash NEVs were fast charged (Level III), each taking almost an hour to charge. Currently, only GEM (a Daimler Chrysler subsidiary) and ParCar are still making products available.

NEV Fleet Testing: The AVTA is also currently Fleet testing 90 NEVs (including some fast charged) in the cities of Palm Valley, Palm Springs, and San Diego, as well as at Luke Air Force base. (The results will be reported at a later date.)

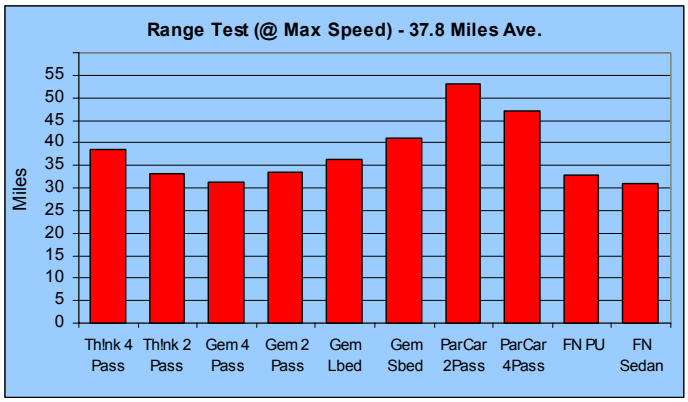

Figure 5. NEV Baseline Performance range testing results. (Pass = passenger, Lbed = long bed, Sbed = short bed, FN = Frazier Nash, PU = pickup.

Urban Electric Vehicles

In partnership with the New York Power Authority, the AVTA has 87 TH!NK *city* UEVs in a commuter fleet demonstration in New York City suburbs; the *city* UEVs are driven from private residences to railroad stations where the commuters catch railroad trains into New York City. (The *city* has a per charge range between 30 miles (drive cycle test result) and 66 miles (constant speed test at 35 mph), with a top speed of 55 mph in one mile).[6] Electric vehicle charging infrastructure for the TH!NK *city* UEVs is located at each commuters' private residence as well as at seven train stations. Eighty-seven commuters are currently using the TH!NK *city* vehicles, with 80% actively providing data to the AVTA.

As of the end of 2003, the participants have driven the vehicles 216,000 miles since Program inception, avoiding the use of almost 9,000 gallons of gasoline. The TH!NK *city* vehicles are driven an average of between 180 and 230 miles per month, and over 95% of all trips taken with the TH!NK *city* vehicles replace trips previously taken in gasoline vehicles. Other information being collected in the New York commuter demonstration program (via an internet-based questionnaire) includes driver demographics (age, income, other household vehicles, etc.), vehicle acceptance and vehicle use. Additional information can be obtained by accessing the NYPA/TH!NK Clean Commute Program Report.[7]

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